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A Unique Archaeological and Geomorphic Record from North-Central New Mexico: Implications to Cultural Resource Management

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A Unique Archaeological and Geomorphic Record from North-Central New Mexico: Implications to Cultural Resource Management

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INTRODUCTION

RIO DEL OSO VALLEY

The Rio del Oso is a permanent stream fed by snow melt, rainfall, and springs. Its narrow watershed begins on the north slope of Chicoma Mountain at 3524 meters elevation, the highest peak in the volcanic Jemez Mountains of north-central New Mexico. The Rio del Oso flows 26 kilometers northeasterly through the Jemez, dropping to 1743 meters elevation where it enters the Rio Chama at the settlement of Chili. Near its confluence with the Rio Chama, the watershed is less than 3 kilomters across. The modern vegetation in the drainage is an Engelmann spruce-cork bark fir forest at high elevation, ponderosa pine and Douglas fir at middle elevations, pinyon pine and juniper woodland and a juniper-shrub grassland at lower elevation. Detailed weather records in Los Alamos County south of Rio del Oso indicate that annual rainfall ranges from about 28 to 89 centimeters from low to high elevations along the eastern slope of the Jemez Mountains (Reneau and McDonald, 1996).

The upper Rio del Oso drainage is developed in the Tschicoma Formation dacite, a series of extrusive flows and domes of late Tertiary volcanic rock at the northeastern margin of the Jemez Mountains (Smith et al., 1970). The lower Oso valley is cut into the weakly indurated Ojo Caliente sandstone member of the Tesuque Formation of the late Tertiary Santa Fe Group (Dethier and Manley, 1985). North-south trending dikes of the black Lobato Basalt are exposed in the lower Oso valley.

Superimposed on eroded Tertiary bedrock are thick deposits of Pleistocene gravels occurring at different elevations along the valley margins of the Rio Chama. The gravels represent former channel and floodplain positions of the Rio Chama and its tributaries. The ages of the gravel terraces are established by amino-acid dating of fossil land-snail shells (Dethier and McCoy, 1993) and the presence of the Pearlette O volcanic ash in the highest terrace (Dethier et al., 1990), indicating that the Rio Chama valley has been downcut 120 meters in the past 600,000 years (Dethier et al., 1988). Along the north slope of the lower Oso valley, Dethier and Manley (1985) map a Pleistocene gravel deposit which forms a prominent terrace about 43 meters above the Oso floodplain.

HOLOCENE FLUVIAL GEOMORPHOLOGY

Modern Channel and Floodplain

The modern floodplain of Rio del Oso is 90 to 215 meters wide in the lower four km of the stream valley before it joins the Rio Chama. The floodplain, with various low benches formed by deposition and scouring of the floodplain surface, is about a meter above the channel margin and is vegetated by grasses and small scattered trees of cottonwood, salt cedar, Russian olive, willow, and elm. Water of the Oso moves through a main channel and at high flow through two connecting channels that are incised through the floodplain deposits. The two ancillary channels are maintained by seasonal strong flow, originating in the early spring by meltwater from snow in the Jemez and in the late summer by runoff from convectional monsoonal rainstorms. The main channel is 55 to 120 cm deep.

Sediments in the main channel consist of very coarse quartz sand and gravel-sized clasts of basalt. The sand is a very pale brown (10YR 7/4), medium to very coarse, and includes basalt clasts ranging from fine to very coarse sand and to granule-cobble-boulder gravels. The grains are subrounded, poorly sorted, and include carbonate-cemented clumps of sand about 1 mm diameter, all of which form weak laminae and some small crossbeds in floodplain deposits adjacent the channel.

Alluvial Stratigraphy and Sedimentology

The late Holocene alluvium of the lower Rio del Oso consists of four to five meters of fine sand and cumulic A-horizon paleosols preserved and exposed along a narrow five-meter high terrace on the north and south margins of the lower Oso valley. Upstream, the valley narrows and the terrace and late Holocene alluvium are largely removed by erosion except for an occasional terrace remnant. The age of the alluvial deposits ranges from 640 to 4,600 radiocarbon years BP, based on twenty-one radiocarbon dates. About 600 years BP, fluvial deposition in the valley halted, and the valley fill was incised, resulting in a channel and floodplain-dominated valley floor and leaving a remnant of the Holocene fill as a five-meter high terrace. Prehistoric fluvial sediments younger than 600 years BP have not been identified.

The late Holocene alluvium is a massive light yellowish brown to pale brown (10YR 6/3-4) fine quartz sand. Slow fluvial aggradation (discussed below) resulted in the development of seven brown to dark grayish brown (10YR 4/2 to 5/3) cumulic A-horizon paleosols, each separated by a zone of lighter-colored fine sand; the cumulic paleosols are also developed in fine sand (Fig. 2). Soil B-horizons or visible secondary carbonates or chemical weathering are not associated with the cumulic soils. The upper boundaries of the paleosols do not form sharp contacts with overlying fluvial sand because of secondary bioturbation that has mixed the sediment, obscuring any sharp contact. The stratigraphic sequence on the south side of the Oso valley appears to have been deposited continuously without stratigraphic interruption in a slowly aggrading floodplain environment; erosional unconformities within the 4000-year sequence are not present.

The alluvium beneath the Holocene terrace on the north side of lower Oso valley differs considerably from the sequence on the south side (Fig. 3). In the lower half of the section, a light yellowish brown sand includes layers of clayey silt, all exhibiting laminae and small crossbeds. A single 25-cm thick cumulic A-horizon paleosol occurs on the north side of the valley. A radiocarbon date indicates that it correlates with paleosol 2 on the south side of the valley. The upper meter of the north-side terrace alluvium is marked by numerous burrow fills and bioturbation. The poor sorting, the alternating sand and silt layers, and the presence of

laminae and crossbeds together indicate stronger stream flow than shown by sediments on the south side of the valley. During the late Holocene, the Rio del Oso channel may have been closer to the north side of the valley than the south, similar to the situation today.

The late Holocene alluvial sediment differs from that being transported by the modern Rio del Oso channel. Modern fluvial sand in the lower Oso contains basalt clasts, derived from outcrops of the Lobato Basalt dikes and younger basalt-bearing Pleistocene gravels upstream in the Oso watershed. Why the modern sand includes basalt particles and the late Holocene alluvium does not is curious and, at present, without explanation.

Radiocarbon Dating

Twenty samples for radiocarbon dating were collected from the thick alluvial section A (by RDP) and one sample from alluvial section B (by SAH) of the late Holocene terrace along Rio del Oso (Table 1). The close-interval samples from section A were analyzed for radiocarbon dating as bulk sediment in which the solid organic matter or humus was dated. Some of the bulk sediment samples have a high charcoal content, perhaps of cultural origin. The single radiocarbon date from section B is on fine charcoal particles from a cultural hearth. The radiocarbon dates were obtained by both conventional and AMS methods after pretreatment to remove carbonates and soluble humates. The conversion of corrected radiocarbon dates to calendar years is calculated by the CALIB 4.1 program (Stuiver and Reimer, 1993; Stuiver et al., 1998). Both radiocarbon years and calibrated years are used as indicated; "yr BP" refers to ^{13}C-corrected radiocarbon years, and "cal yr" refers to calibrated years that are derived from the CALIB 4.1 program. Calibrated years approximate calendar AD/BC years but cannot be regarded as precise equivalents.

The large number of radiocarbon dates from section A allows us to identify two stratigraphically-reversed dates which, because of their magnitude, cannot be explained by turbation, the common cause of age inversion (Fig. 4). Both incongruous dates are younger than their stratigraphic position indicates, the stratigraphically lower sample too young by 2000 cal years and the upper one by 1700 cal years, based on comparison with the sedimentation rates calculated from the other 18 calibrated ages from section A terrace alluvium. When the two incongruous ages are removed from the series, linear regression analysis of calibrated age versus depth shows a strong correlation, $r^2 = 0.960$ (Fig. 5).

Two additional cases of age-inversion occur in section A, between 200 and 250 cm depth and between 300 and 350 cm depth. However, the degree of age-inversion is small, and because of this, it is not possible to determine if the inversion is related to specific radiocarbon dates that are too young or too old. Slight age inversions may be caused by bioturbation of the fine sandy alluvium and mixing of its organic-matter content.

The ability to recognize either coarse- or fine-scale stratigraphic-age inversion of radiocarbon dates is due in this case to the large number of dates from successive stratigraphic levels within section A. If, instead, only a few radiocarbon dates had been obtained from widely separated zones, it is unlikely that any evidence of radiocarbon-date inversion could be identified.

Sedimentation Rate

The net rate of sedimentation has been determined by linear regression of calibrated radiocarbon ages versus measured depth at section A; the correlation of age versus depth is very strong,

$r^2 = 0.960$ (Fig. 5). The net sedimentation rate for the entire alluvial section is 7.65 cm/100 cal years, a value which, compared with other alluvial records in the region, is low. As a consequence of slow sedimentation, seven cumulic A-horizon soils formed on the valley floor between 600 and 5300 cal years BP.

Closer inspection of the calibrated ages of the terrace alluvium shows two sub-trends. The four ages from the upper one-meter of fill indicate a more rapid net sedimentation rate between cal AD 950 and 1350, a net rate of 14.3 cm/100 cal years, twice that of the overall average for the Oso terrace. This is preceded by a period of much slower deposition; the stratigraphic interval between 1.15 and 2.15 meters depth has a net sedimentation rate of 4.88 cm/100 cal years during the period cal BC 1260 to AD 540. Prior to BC 1300, net aggradation approximates the average value for Rio del Oso alluvium, although reversed dates in the lower two meters of the alluvial deposits may obscure fine-scale trends in sedimentation rates.

Cumulic A-horizon Paleosols

Soils form by chemical weathering of stable surfaces and landforms. However, during periods of slow deposition, over-thickened cumulic A-horizon soils form on floodplains and valley floors. Cumulic soils form with slow deposition of clastic particles by overbank or spreading flow. Turbation mixes the clastic particles with decomposing plant material, producing an organic-rich A-horizon. Cumulic soils generally do not exhibit weathering properties or B-horizons unless the surface on which the A-horizon soil has formed is no longer subject to flooding and deposition for an extended period of time, such as would happen if the surface is isolated as a terrace by downcutting of the valley floor.

Seven cumulic A-horizon paleosols, ranging from 5 to 62 cm thick, formed in the slowly aggrading environment of the lower Oso valley during the late Holocene. The paleosols are numbered 1 through 7, from the top of the terrace to the base of the exposure, and collectively are 41% of the stratigraphic record. The paleosols are all developed in fine to medium quartz sand and are dark grayish brown to brown (10YR 4/2 to 5/3) which, in contrast to the pale brown sand between paleosols, are visibly prominent in outcrop exposures because of their dark color. The paleosols are moderately calcareous, some carbonates occurring as filaments that follow small roots, although the paleosols are no more calcareous than are the intervals of sandy alluvium between paleosols. None of the paleosols exhibit secondary pedogenic B-horizon characteristics of even weakly developed soils, such as blocky structure or chroma differences. The basal and top boundaries of the paleosols are generally obscured by burrow fills and bioturbation. The chronology of the paleosols from section A alluvium is derived from twenty radiocarbon dates. Close inspection of calibrated ages of both paleosol and non-paleosol intervals, however, does not indicate differences in sedimentation rates. Although the Oso alluvium is well-dated by modern standards, greater chronologic resolution is necessary to identify subtle differences in sedimentation rates for paleosol versus non-paleosol zones.

The Holocene alluvial sequences in the region generally consist of sandy sediments, and cumulic A-horizon paleosols are uncommon, especially multiple paleosols such as occur in the lower Oso valley. The explanation for why the Oso valley is different may lie in its geomorphology and hydrology. The lower Oso valley is wide and its gradient is comparatively low, resulting in the development of a wide floodplain. The following circumstances may have contributed to cumulic soil development: the perennial flow of the Rio del Oso, the presence of a high alluvial water table, and a moist fine sandy soil promoting the growth of abundant grasses and graminoid sedges on the floodplain surface. The spreading out of water over the wide floodplain during

episodes of high flow would result in slow floodplain aggradation by the deposition of suspended fine sediments on a densely vegetated surface. Slow sedimentation and the contribution of organic matter from the floodplain grass cover set the stage for the development of a organic-rich cumulic soil. The lower Rio del Oso valley is characterized by a low net rate of sedimentation, measured as 7.65 cm per 100 calibrated years, which is sufficiently slow to account for the multiple cumulic A-horizon paleosols observed in the late Holocene alluvium. Possible influences to floodplain sedimentation by prehistoric cultural activity at Oso have not been observed. The geomorphic history of the valley may be explained by geologic processes acting alone without human influence.

VALLEY-FILL HISTORY AND PALEOECOLOGY

Geomorphic studies of terraces abound in the region (i.e., Pazzaglia and Wells, 1990) but generally lack accompanying stratigraphic and sedimentologic information than can be used to correlate within a single drainage basin, and, in too many cases, the absence of a high-resolution radiocarbon chronology makes it difficult to correlate the geomorphic history of one area to that of another. If patterns of cause-and-effect relationships between climate and geomorphic events are to be established, high-resolution geomorphic records must be accompanied by high-resolution dates and matched by high-resolution paleoclimatic records that are in turn well-dated and unambiguous. Further, if changes in the physical and biotic landscape are to be equated with prehistoric cultural ecology, the archaeological record must have a firm chronology as well.

A detailed late Holocene history of the Rio del Oso is preserved in the stratigraphy, paleosols, and sedimentology of the terrace alluvium. Between 640 and 4600 radiocarbon years BP, the lower Oso floodplain slowly aggraded at a net rate of only 7.65 cm/cal 100 yr resulting in a series of seven cumulic A-horizon paleosols which together make up 41% of the stratigraphy at section A on the south side of the valley. The continuity of alternating cumulic soils and fine sand indicate a generally stable fluvial environment during the late Holocene.

However, the upper two meters of the terrace show changes in sedimentation rates which may be related to climate change in the Jemez Mountains and Rio del Oso watershed. Between 1530 and 3010 radiocarbon years BP, floodplain deposition was 4.88 cm/100 cal yrs, a very low rate of accumulation. By 1160 yr BP at Oso, the sedimentation rate shifted to 14.3 cm/100 cal yrs, a higher rate of floodplain deposition which persisted until the valley was trenched at about 600 yr BP. The change from low to high sedimentation rates may represent a shift from a comparatively moist to drier climate. Moist conditions promote greater plant cover, reducing sediment availability to overland flow and resulting in less suspended load in streams and lower rates of fluvial deposition. A shift to drier climate results in reduced plant cover, increasing sediment availability to overland flow, resulting in more suspended load and higher rates of deposition. A similar pattern of fluvial response to climate change is reported from the southern plains (Hall, 1990).

Fluvial deposition on the late Holocene floodplain in the Oso valley continued until 640 radiocarbon yr BP, after which time the valley was incised by channel cutting. The Oso record of channel incision at 600 yr BP is unusual. Other alluvial records in the south-central and southwestern United States show widespread channel erosion at 1000 yr BP; many of these records, such as Chaco Canyon and Rio Tesuque, show renewed alluvial deposition by 800 yr BP (Hall, 1977, 1990; Miller and Wendorf, 1958).

Recent studies on the Pajarito Plateau focus on alluvial terraces and soils developed on the terraces and provide comparative records for the results from Rio del Oso. In Sandia and Ancho canyons, sequences of alternating floodplain and channel deposits represent a period of general aggradation between 1200 and 4800 yr BP (Reneau and McDonald, 1996, p. 46-48, 68-69). In contrast, rapid downcutting in Rendija Canyon has led to a series of stepped terraces, each inset into and at lower elevation than the other. The three younger terraces are Holocene. Sediments in the five-meter Qt6 terrace are dated 5200 to 6900 yr BP, the inset younger three-meter high Qt7 terrace is dated 3200 yr BP, and the youngest Qt8 terrace which forms the canyon floor about one meter above the modern channel is dated 490 to 1580 yr BP (McDonald et al., 1996).

The late persistence of aggradation in Rendija Canyon matches that from Oso. However, the inset late Holocene terraces in Rendija Canyon are not seen at Oso nor in other fluvial geomorphic records from the region. Even though both Oso and Rendija sequences are unusually late, both ending about 500 to 600 years BP, the contrasting continual sedimentation at Oso with the episodic downcutting and filling at Rendija indicates that both records are fundamentally different and may be driven by different processes.

ARCHAEOLOGY

CRM

SUMMARY AND CONCLUSIONS

[Richard, once you write your part, we can write a summary/conclusions that bring the paper together]

REFERENCES CITED

Dethier, D. P., Harrington, C. D., and Aldrich, M. J.
1988 Late Cenozoic rates of erosion in the western Espanola Basin, New Mexico: Evidence from geologic dating of erosion surfaces. Geological Society of America Bulletin, v. 100, p. 928-937.

Dethier, D. P., Halverson, N., Marrack, L., Meagher, M., Oelkers, E., Harrington, C. D., Sarna-Wojcicki, A, and Meyer, C. E.
1990 Occurrence of the Lava Creek B tephra layer in the northwestern Espanola Basin, New Mexico. New Mexico Geology, v. 12, p. 77-82.

Dethier, D. P., and Manley, K.
1985 Geologic map of the Chili quadrangle, Rio Arriba County, New Mexico. U.S.Geol. Survey, Misc. Field Studies Map MF-1814, scale 1:24,000.

Dethier, D. P., and McCoy, W. D.
1993 Aminostratigraphic relations and age of Quaternary deposits, northern Espanola Basin, New Mexico. Quaternary Research, v. 39, p. 222-230.

Hall, S. A.
1977 Late Quaternary sedimentation and paleoecologic history of Chaco Canyon, New Mexico. Geological Society of America Bulletin, v. 88, p. 1593-1618.

1990 Channel trenching and climatic change in the southern U.S. Great Plains. Geology, v. 18, 342-345.

McDonald, E. V., Reneau, S. L., and Gardner, J. N.
1996 Soil-forming processes on the Pajarito Plateau: Investigation of a soil chronosequence in Rendija Canyon. New Mexico Geological Society, Guidebook 47, p. 367-374.

Miller, J. P., and Wendorf, F.
1958 Alluvial chronology of the Tesuque valley, New Mexico. Journal of Geology, v. 66, p. 177-194.

Pazzaglia, F. J., and Wells, S. G.
1990 Quaternary stratigraphy, soils and geomorphology of the northern Rio Grande rift: New Mexico Geological Society, Guidebook 41, p. 423-430.

Reneau, S. L., and McDonald, E. V.
1996 Landscape History and Processes on the Pajarito Plateau, Northern New Mexico. Rocky Mtn. Cell, Friends of the Pleistocene, Field Trip Guidebook, 195 p.

Smith, R. L., Bailey, R. A., and Ross, C. S.
1970 Geologic map of the Jemez Mountains, New Mexico. U.S.Geol. Survey Misc. Investigations Series, Map I-571, scale 1:125,000.

Stuiver, M., and Reimer, P. J.
1993 Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. Radiocarbon v. 35, p. 215-230.

Stuiver, M., Reimer, P. J., Bard, E., Beck, J. W., Burr, G. S., Hughen, K. A., Kromer, B., McCormac, G., van der Plicht, J., and Spurk, M.
1998 INTCAL98 radiocarbon age calibration, 24,000–0 cal BP. Radiocarbon v. 40, p. 1041-1083.

FIGURE EXPLANATIONS

Fig. 1. location map [still to be put together]

Fig. 2. Late Holocene alluvial stratigraphy, section A, south side Rio del Oso, Rio Arriba Co., New Mexico; radiocarbon dates in ^{14}C years BP, see Table 1; dates in parentheses are stratigraphically-reversed, see Fig. 4.

Fig. 3. Late Holocene alluvial stratigraphy, section B, north side Rio del Oso, Rio Arriba Co., New Mexico; paleosol correlates with paleosol 2 of section A.

Fig. 4. Corrected radiocarbon dates (not calibrated) versus depth with numbered paleosols from section A, Rio del Oso; solid line connects radiocarbon dates in stratigraphic sequence; two stratigraphically-reversed dates are shown in gray; linear regression of all twenty dates including reversed dates has r^2 value = 0.840.

Fig. 5. Calibrated radiocarbon ages (intercepts) versus depth from section A, Rio del Oso; excludes the two stratigraphically-reversed dates that are shown in gray in Fig. 4; the multiple overlapping dots of some radiocarbon dates represent more than one intercept for calibrated age, data from Table 1; net sedimentation rate is 7.65 cm per 100 cal years; linear regression has r^2 value = 0.960 even though some dates exhibit minor stratigraphic inversion.

Fig. 6. Cross-section of lower Rio del Oso, Rio Arriba Co., New Mexico. [still to be drawn]

Table 1. Radiocarbon dates, Rio del Oso alluvium

level	*cm depth*	*lab no.*[A]	*measured ^{14}C age*[B]	*$\delta^{13}C$*[C]	*corrected ^{14}C age*	*calibrated age, yr BP*[D]	*calibrated age range, AD/BC*[E]
Alluvial Section A							
1	18-22	Beta-104591	640 ± 80	*-25.0*	640 ± 80	568,581,648	AD 1253-1433
2	38-42	Beta-104590	730 ± 70	*-25.0*	730 ± 70	668	AD 1164-1333
3	58-62	Beta-104589	950 ± 60	*-25.0*	950 ± 60	802,913	AD 994-1214
4	88-92	Beta-104588	1100 ± 60	*-25.0*	1100 ± 60	974,1046	AD 781-1025
5	114-116	Beta-104587	1520 ± 50[L]	-24.4	1530 ± 50	1410	AD 426-623
6	148-152	Beta-104586	1710 ± 80	*-25.0*	1710 ± 80	1575,1609,1684	AD 133-531
7	173-177	Beta-104585	2120 ± 60	*-25.0*	2120 ± 60	2116	BC 257-15
8	214-216	Beta-104417	2930 ± 60[K]	-20.3	3010 ± 60	3210,3234	BC 1404-1105
10	239-241	Beta-104416	2900 ± 50[K]	-12.4	3110 ± 50	3350	BC 1463-1260
11	249-251	Beta-104584	2930 ± 50[L]	-23.9	2950 ± 50	3079,3091,3105 3128,3156	BC 1310-1005
12	258-262	Beta-104583	2810 ± 100	*-25.0*	2810 ± 100	2885,2908,2920	BC 1220-801
13	264-266	Beta-104582	3120 ± 60[L]	-23.9	3140 ± 60	3361	BC 1524-1260
14	278-282	Beta-104581	3510 ± 60	*-25.0*	3510 ± 60	3730,3744,3776 3789,3826	BC 1973-1688
15	293-297	Beta-104580	3570 ± 80	*-25.0*	3570 ± 80	3844,3865	BC 2136-1734
16	309-311	Beta-104579	3800 ± 50[L]	-25.4	3800 ± 50	4152,4174,4207 4219	BC 2407-2126
17	319-321	Beta-104415	4000 ± 60[K]	-11.0	4230 ± 60	4829	BC 2924-2620
18	348-352	Beta-104578	3780 ± 50	-25.9	3760 ± 50	4093,4116,4145	BC 2335-2026
19	358-362	Beta-104577	2780 ± 100	*-25.0*	2780 ± 100	2866	BC 1213-794
20	399-401	Beta-104414	4520 ± 60[K]	-19.7	4610 ± 60	5315	BC 3524-3279
24	459-461	Beta-104576	3540 ± 50[L]	-25.4	3540 ± 50	3783,3831	BC 1980-1740
Alluvial Section B							
--	165-170	Beta-104419	2540 ± 50[K]	-19.2	2630 ± 50	2751	BC 906-758

A = material dated from section A is solid organic matter or humus from bulk sediment; material dated from section B is charcoal

B = radiocarbon ages with notation (K = Kiel; L = Lawrence Livermore National Laboratory) are measured by AMS; radiocarbon ages are in radiocarbon years before present and are calculated using the Libby half life (5568 years); samples without notations are measured by conventional methods

C = $^{13}C/^{12}C$ ratios in italics are estimated and have not been measured; "$^{13}C/^{12}C$ ratios for samples measured at Kiel...are measured in the accelerator itself...and should not be interpreted as the isotopic ratio of the original material" (letter, Beta Analytic, Inc., 1997)

D = calibrated intercepts of corrected radiocarbon years to calendar years BP (0 yr BP = AD 1950); calculated by CALIB 4.1

E = calibrated age range to calendar years AC/BC; the highest 2-sigma probability distribution is presented in this column; calculated by CALIB 4.1(Stuiver and Reimer, 1993; Stuiver et al., 1998)

Fig. 2

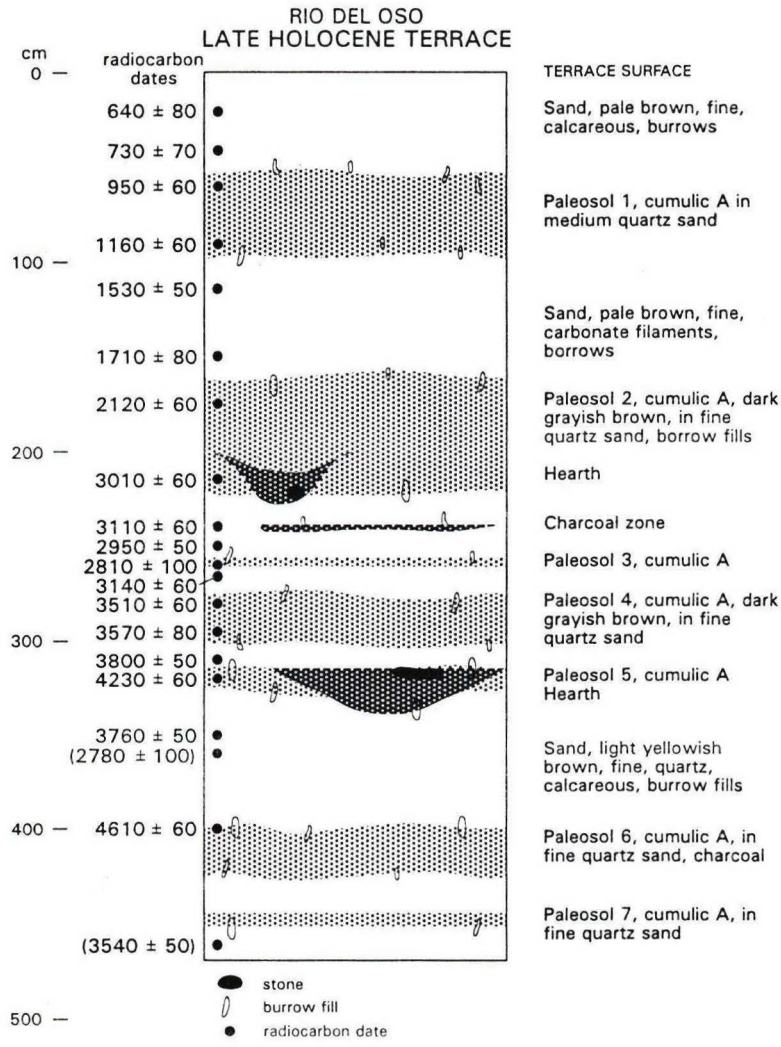

RIO DEL OSO
LATE HOLOCENE TERRACE
cm
0
radiocarbon dates
640 ± 80
730 ± 70
950 ± 60
1160 ± 60
100
1530 ± 50
1710 ± 80
2120 ± 60
200
3010 ± 60
3110 ± 60
2950 ± 50
2810 ± 100
3140 ± 60
3510 ± 60
3570 ± 80
300
3800 ± 50
4230 ± 60
3760 ± 50
(2780 ± 100)
400
4610 ± 60
(3540 ± 50)
500
stone
burrow fill
radiocarbon date
TERRACE SURFACE
Sand, pale brown, fine, calcareous, burrows
Paleosol 1, cumulic A in medium quartz sand
Sand, pale brown, fine, carbonate filaments, borrows
Paleosol 2, cumulic A, dark grayish brown, in fine quartz sand, borrow fills
Hearth
Charcoal zone
Paleosol 3, cumulic A
Paleosol 4, cumulic A, dark grayish brown, in fine quartz sand
Paleosol 5, cumulic A
Hearth
Sand, light yellowish brown, fine, quartz, calcareous, burrow fills
Paleosol 6, cumulic A, in fine quartz sand, charcoal
Paleosol 7, cumulic A, in fine quartz sand

Fig. 3

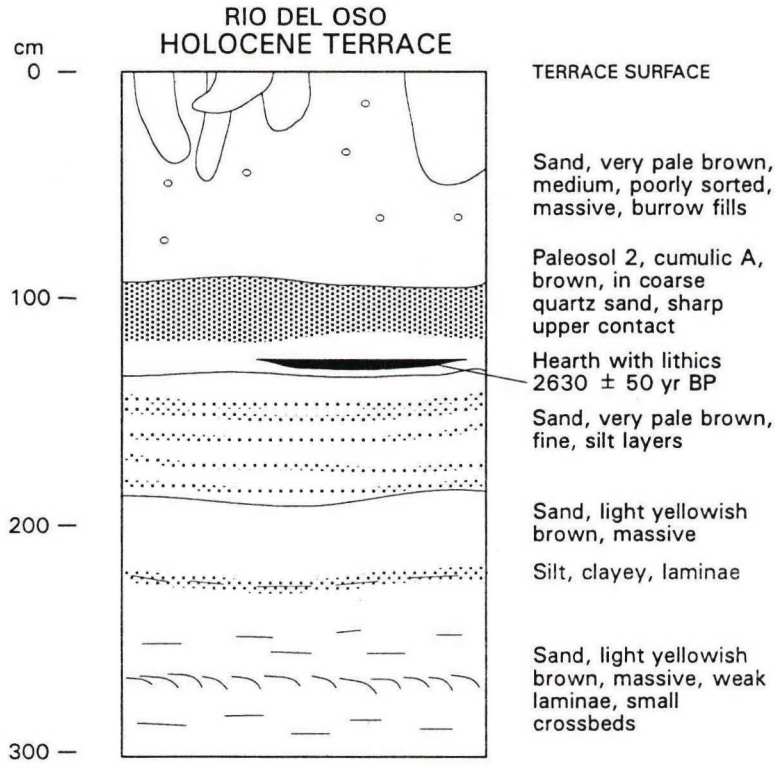

RIO DEL OSO
HOLOCENE TERRACE
cm
0
100
200
300
TERRACE SURFACE
Sand, very pale brown, medium, poorly sorted, massive, burrow fills
Paleosol 2, cumulic A, brown, in coarse quartz sand, sharp upper contact
Hearth with lithics
2630 ± 50 yr BP
Sand, very pale brown, fine, silt layers
Sand, light yellowish brown, massive
Silt, clayey, laminae
Sand, light yellowish brown, massive, weak laminae, small crossbeds

Fig. 4

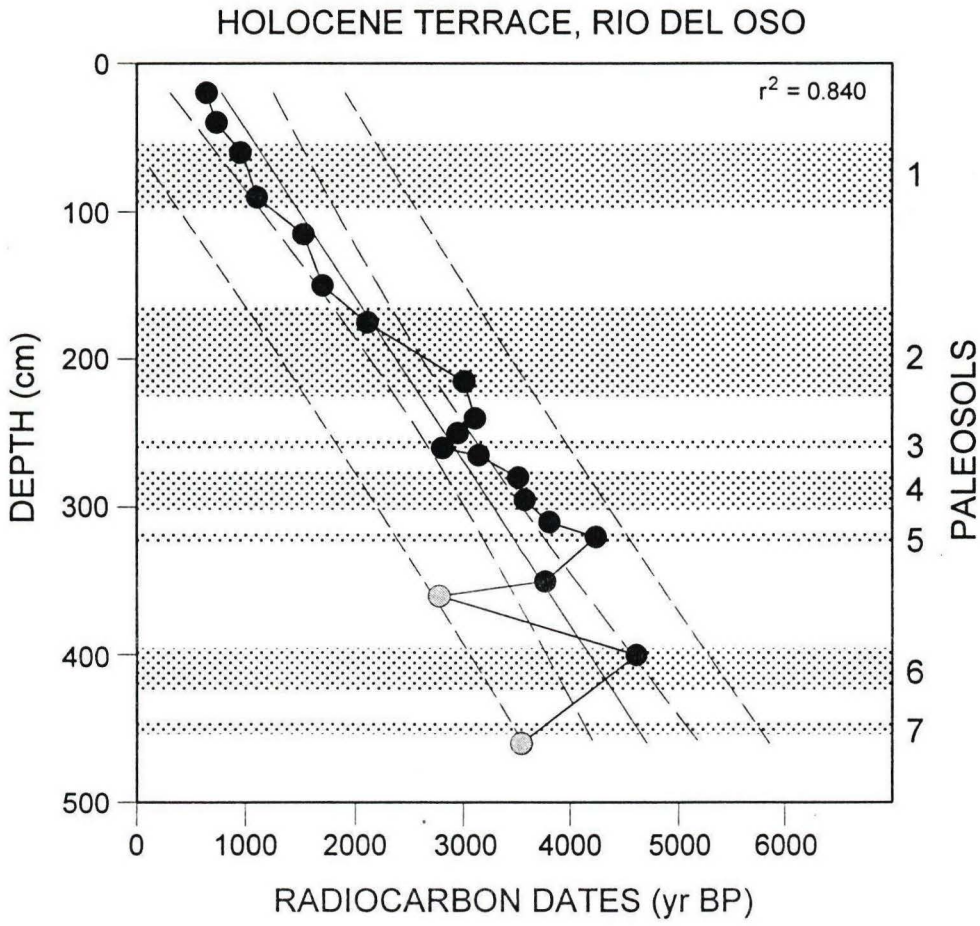
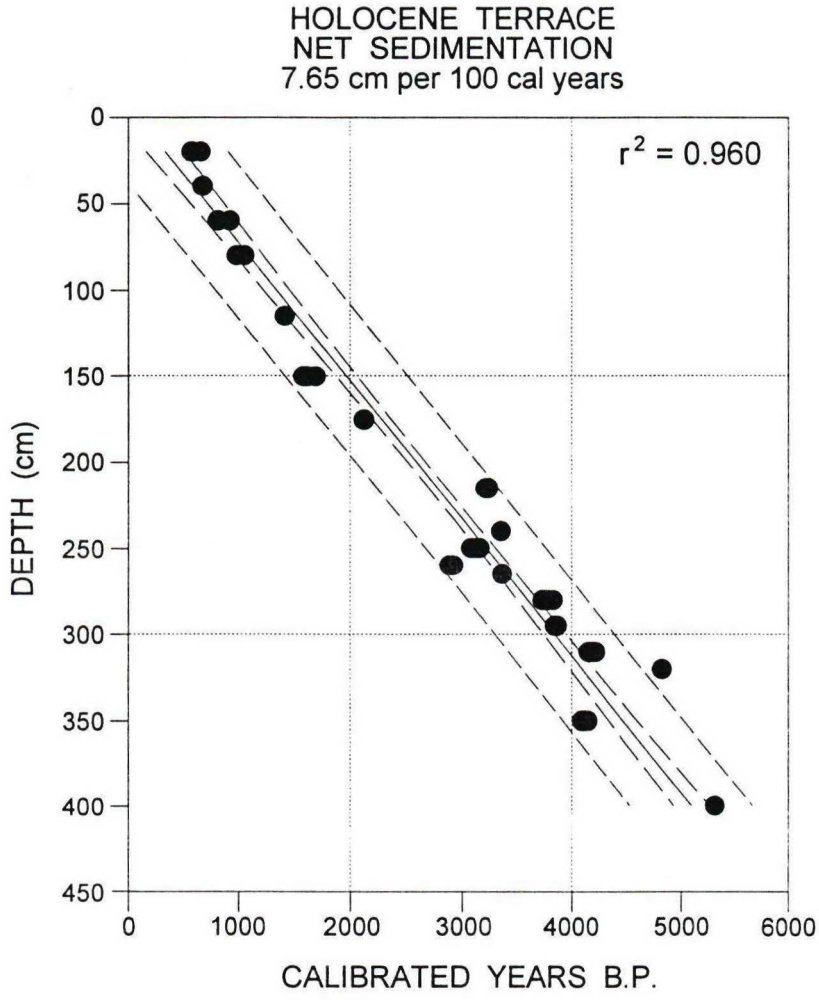

HOLOCENE TERRACE, RIO DEL OSO
r^2 = 0.840
DEPTH (cm)
0
100
200
300
400
500
0
1000
2000
3000
4000
5000
6000
RADIOCARBON DATES (yr BP)
PALEOSOLS
1
2
3
4
5
6
7

Fig-5


HOLOCENE TERRACE
NET SEDIMENTATION
7.65 cm per 100 cal years
r^2 = 0.960
DEPTH (cm)
0
50
100
150
200
250
300
350
400
450
0
1000
2000
3000
4000
5000
6000
CALIBRATED YEARS B.P.